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CHALLENGES OF EXPERIMENTING R1234YF REFRIGERANT FOR AUTOMOBILE HVAC SYSTEM – A REVIEW

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ABSTRACT

New refrigerants are on the verge of hitting the automobile HVAC industry, on account of several threatening conditions. Zero ozone depletion potential (ODP) and low global warming potential are the major challenges looked at by many researchers. This paper, summarizes the challenges of experimenting R1234yf refrigerant for automobile HVAC system. Major factors considered are cost, efficiency, experiments, two-phase flow mechanisms, thermophysical properties, regulatory gauges, operation and maintenance. Survey results of the refrigerant reveal that, there is no evidence of breakdown. Apart from a significant reduction in global warming potential (GWP), R1234yf requires high work for the compressor with shorter cycle run-time of compressor.

KEYWORDS*: *Global Warming Potential (GWP), Ozone Depletion Potential (ODP), Thermophysical Properties, Two-Phase Flow, Cost Efficiency & Regulatory Gauges

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A Review

INTRODUCTION

Refrigerants with greater warming importance have been used as refrigerants in different applications. The Montreal Protocol set up in 1987 states that, such refrigerants with a greater global warming importance were deteriorating the layer of ozone, and suggested the replacement of such refrigerants with refrigerants with a reduced importance of global warming. Further, the EU (European Union) has banned the use of R134, essentially in mobile AC of new models, effective in 1st January 2011. Refrigerant R134a is a similarly used refrigerant in cycles of vapor compression, particularly in automotive AC systems. The potential of global warming of R134a is 1430, as contrast to carbon dioxide, which under the phrase of Montreal Protocol refers as required to be phased out by 2013, and automotive AC systems required to predict a new refrigerant with a reduced potential of global warming (Reasor et al, 2010). According to Minor and Spatz (2008), R1234yf has been suggested as a replacement for R134a in mobile AC systems. R1234yf has a potential of global warming of 4, which will meet the needs of European Union. R1234yf has comparable properties of thermodynamics to R134a which makes it ideal as a replacement, as it may be feasible for no or few needed changes to replace R134a with R1234yf in a pre-designed system. Additionally, R410A is used in refrigeration systems commonly, and R1234yf may be a feasible replacement for that refrigerant as well.

REGULATORY GAUGES (GWP AND ODP)

Vijay and Pratihar (2014) have described that, R134a refrigerant is used widely in mobile AC and causes global warming with a GWP (global warming potential) of 1300. This means that, the discharge of 1 kilogram of R134a is common to 1300 kilogram of carbon dioxide. R134a is stable in atmosphere for long time and has life

time of atmosphere of thirteen years. Several examinations have been organized in the study into substitutes for R134a. The below table shows (Table 1) the features thermodynamic properties of R1234yf and R134a:

Table 1: Thermodynamic Properties of R1234yf and R134a

Thermodynamic Property	R1234yf	R134a
Chemical Formula	C3F4H2	CF_3CH_2F
Molar Mass (kg/kmol)	114.04	102.03
Boiling Point at 1 atm (K)	243.70	247.08
Freezing Point (K)	unknown	169.85
Critical Temperature (K)	367.85	374.21
Critical Pressure (MPa)	3.38	4.06
Critical Density (kg/m3)	478.01	511.90

There is a requirement for better alternatives, which have zero ODP (ozone depletion potential) and lower or zero GWP (global warming potential). R1234yf is a new refrigerant which has reduced GWP (global warming potential) than R134a. R1234yf has GWP (global warming potential) of 4, so it fulfills the directive of MAC passed in 2006 July. Maintaining greater coefficient of performance was not as essential at the time because, the prices of energy were low relatively. Nowadays, greater coefficient of performance is much essential for two reasons, namely overall costs of energy are substantially greater than the change in last refrigerant, and coefficient of performance decreases with lower global warming potential refrigerants in several cases. Coefficient of performance is the refrigeration ratio impact to input of network give to the system. Ulrich (2014) has mentioned that, the vapor compression refrigeration system of coefficient of performance can be developed either by developing the refrigeration impact or by reducing input of work given to the system. It is predicted that, almost entire vehicles equipped with an AC system use R134a as a refrigerant. Due to the motor vehicle directive of European Community, refrigerants with a global warming potential greater than 150 are not permitted from 1st January 2017 in new passenger cars for sustainability of environment. Thus, a replacement for R134a is required. The suggested refrigerant substitute is R1234yf, which has same properties of thermodynamics and a reasonable replacement of retrofit for R134a with changes in expansion valve. Esbr et al (2013) has stated that, an experimental examination using refrigerants R134a and R1234yf without and with the existence of internal heat exchanger under vast number of working condition has been learnt. The outcomes revealed that, reduction in coefficient of performance and capacity of cooling have been examined between 13 and 6 percent, when R134a is replaced by R1234yf in the existence of reduction of internal heat exchanger in between 6 and 2 percent. According to Minxia, Chaobin and Eiji (2012) R1234yf has nearly common value of normal boiling point and molecular weight making R1234yf a better replacement of R134a. It can be realized that R1234yf has been suggested for mobile AC, due to its reduced global warming potential and performance, contrast to that of R134a. However, its performance is inferior to that of R410a. This makes it critical to be used to residential AC mentioned that AC is integral for modern cars, specifically in high temperature areas like tropics (Alison et al, 2014). Santanu et al (2014) has mentioned that automotive air conditioning regulates air as per cabin condition, specifically the humidity and temperature. This is not only to offer comfort, but also for safety and health reasons, because the concentration level of driver alters with the AC in the cabin. With the urgent requirement to make cars much energy effective due to developed prices of fuel and the harmful impacts of greenhouse gases, it is essential to decrease the automotive air condition energy consumption. The condition of optimum operation with blower speed and compressor along with charge level of refrigerant has been recognized for car AC system. Kilicarslan and Kurtbas (2012) have described that the system steady state performance has been examined for 3 independent variables namely, the charge level of refrigerator, evaporator fan speed and compressor speed, as they are the only parameters of variable for a running

car. The impacts of incoming air dry bulbs temperature to relative humidity, coil, leaving temperature of air dry bulb from coil on transfer of heat and destruction of energy are examined by means of a node developed by computer.

COST AND EFFICIENCY OF R1234YF OVER OTHER REFRIGERANTS:

The automotive AC system of R134a evaluation with a variable compressor capacity was learnt by Saiz Jabardo et al (2002). They evolved a model of computer simulation, which involves a compressor of variable capacity and expansion valve of thermostatic, in addition to micro channel and evaporator parallel flow condenser. The design parameters' effects on performance of system of the speed of compressor return air to evaporator and condensing temperatures of air have been simulated experimentally, by means of developed model. Comparative performance of an automotive AC system of R134a using variable and fixed capacity compressors was learnt by Alkan and Hosoz (2010). They inferred that the variable speed compressor operation generally produces a greater coefficient of performance than the fixed speed compression operation, in expense of a reduced cooling capacity. Jitendra Verma et al (2013) have undertaken a description of alternative to R134a refrigerant. They mentioned that, R152a is a direct drop in substitute for R134a. The molecule is similar to R134a, except that two atoms of hydrogen are substituted for two fluorine atoms. It has same operating features to R134a but cools even better. An environmental advantage of R152a is that, it has a rating of global warming of ten times less than R134a. Ghodbhane (2000) simulate the automotive AC systems performance with many hydrocarbons. He determined that, the system with R270 and R152a provide a good performance than the one with R134a. Additionally, a comparative assessment of secondary loop system performance using these refrigerants is offered.

Navrarro et al (2013) presented a comparative study between R134a, R290 and R1234yf for an open piston compressor of automotive AC at varied conditions of operation. The text matrix consist o two speeds of compressor, condensation temperatures and evaporation temperatures. They inferred that R290 was revealed an essential growth in volumetric efficiencies and compressor while R1234yf develop its efficiencies, contrast to R134a for ratios of pressure greater than eight. Novarro-Esbri et al (2013) undertook an experimental examination of R1234yf, as a drop in replacement for R134a in a vapor compression system. The tests of experiment were undertake differing the evaporating temperature, condensation temperature, the compressor speed, the superheating degree and the use of internal heat exchanger. Comparisons are made taking refrigerant R134a as baseline, and the results reveal that the cooling capacity acquired with R1234yf is around 9 percent smaller than acquired with R134a. Claudio Zilio et al (2011) learnt an automotive AC system, experimentally equipped with compressor of variable displacement. They inferred that the R1234yf systems indicate smaller performance than R134a system at a given capacity of cooling. Lee and Jung (2012) undertook a detailed performance comparison of R134a and R1234yf in a bench tester for applications of automobile. They inferred that the COP and capacity of cooling of R1234yf were 3 percent and 4 percent smaller than that of R134a, respectively. Gustavo, Potker (2015) learnt the impact of condenser sub-cooling on AC system performance, operating with R1234yf and R134a. It was inferred that the coefficient of performance of the system operating with R1234yf can advantage greater from sub-cooling of condenser than with R134a and due variations in thermodynamic properties. The eco friendly refrigerant R1234yf is an alternative of R134a in mobile AC application, with developing indoor set temperature and smaller air lift. Thus, it can be inferred that, the R1234yf refrigerant performance is common to all parameters in R134a refrigerant, and R1234yf is regarded as the best thermal performance among entire refrigerants.

TWO-PHASE FLOW MECHANISMS

Fei, Hrnjak, (2004) expressed that the focus of the study is the evolving two-phase flow in parallel manifolds with descending facing departures, in close immediacy to the growth device. The efficiency of heat exchangers is intensely affected by the distribution of the refrigerant two-phase flow specifically liquid phase in the manifold, generally called a header. The misdistribution in parallel tracks is pointedly related to the two-phase flow outlines in the header, as well as some other influences containing non-uniform thermal loading of various sections of the heat exchanger, fouling possessions, etc. The inlet form, fluid stuffs, positioning and geometry of the header define the flow pattern of two-phase flow. It also has all the abilities to resolve the fluid flow problems, that drop in an extensive variety of categories 17, ranging from laminar flows in meek geometries to wild multiphase flows in compound geometries with heat transmission or difficulties in the HVAC and electronic packaging industries.

Bandar, Luiz, Hussam, (2015) examined the application of CFD forming to act out the two-phase heat transfer devices in a wickless heat pipe, also known as a thermo syphon. Two refrigerants, R134a and R404a, have been selected as the working fluids of the examined thermo syphon. A CFD model was assembled to simulate the details of the two-phase flow and heat transfer incidences, during the early stage and steady-state process of the thermo syphon. The CFD simulation outcomes were being associated with experimental quantities, with good contract acquired between expected temperature profiles and experimental temperature facts, thus authorizing that the CFD model is being successful in replicating the heat and mass transfer methods in the R134a and R404a indicted thermo syphon. Heat pipes have been effectively recycled for waste heat energy retrieval in a huge range of engineering presentations, such as heating, ventilation, and air conditioning (HVAC) systems.

Sreelal, Hariharan, (2014) clearly expressed the main experiments of the engineers in the air conditioning field are the environmental harm, due to CFC and power ingestion of the system. The liquid hygroscopic substance in air conditioning system, which could covenant with the suppressed load self-sufficiently with desiccant immersion has been observed as associable and alternate for energy saving. The dropping film liquid desiccant air conditioning system is likely to accomplish a low pressure drop and low probability of solution droplet carried out by air. The objective of this paper is to study the effect of velocity of air on the heat and mass transmission in the falling film variety liquid desiccant dehumidifier, which reduces the level of humidity in the air. FLUENT uses a determinate volume method and needs from the user to deliver the grid system, physical possessions and the boundary conditions.

Gowreesunker, Tassou, Kolokotroni, (n.d) stated that TRNSYS-CFD quasi-dynamic coupled simulation system is being used for the analysis, whereby TRNSYS act out the HVAC and PID control system and ANSYS FLUENT is used to simulate the airflow within the airport terminal space. The thermal capacity of the building and its daily variation, the necessary heat transfer rates, the kind of auxiliary heating, ventilation and air-conditioning (HVAC) systems are being used, are some of the significant parameters to be measured in the collection of an applicable PCM system. PCMs can be combined as PCM-plates or PCM nodes in the HVAC system for free air-conditioning, or in loading tanks. As a result, the HVAC system is being used in airports plays an important role in sustaining the different thermal comfort necessities in the various spaces, and generally energy necessities of the indoor environment.

Amel, et al (2009) deals with comparisons between CFD and experimentations for a supersonic ejector. Good results are offered in terms of entrainment rate related to home-made investigational data for an air conditioning.

Furthermore, it is verified that the justification of an over-all performance parameter, such as the entrainment rate which used to carry along in a current or into the vapor phase, is not necessary for a correct valuation even though an extensive range of process is tried out. Certainly, the same calculation both simulations may give very different local flow structures. Lastly, a first try to tackle two-phase aspects is also being accomplished and executed experimentally and by replications.

Debashis, et al (2012) expresses a spot, or circulated, cooling and heating is an energy effective way of delivering ease method to an occupant in the car. This paper defines a method to spread cooling in the vehicle. The objective of this paper is to concentrate on the design and CFD exploration of the energy resourceful HVAC system with spot cooling. A standard system with conventional HVAC air has been analysed initially at middle and high ambient conditions. The airflow and cooling supplied to the driver and the passenger has also been calculated. Later, spot cooling has been analysed in combination with a much lower conventional HVAC airflow. Lower cooling condition on the predictable HVAC system due to spot cooling is the major thing for energy savings accomplished in AC mode.

Gokhan, Muhsin, (2013) have stated that the aim of this paper is to present a three dimensional transitory cooling exploration of an automobile cabin with an effective making under solar radiation. In the statistical models, the speed and the temperature circulations in the automobile cabin along with the human body surfaces is being calculated during transient cooling period. The surface-to-surface radiation model has been used for controls of radiation heat transfer between the inner surfaces of the automobile cabin and a solar load system, which can be used to analyse radiation effects. It becomes essential to diminish heat loads that enter passenger compartments difficulties in an initial stage of vehicle design and energy plays an essential role on the thermal security in the compartment. Thus, engineers would like to design and implement more effective HVAC systems of automobiles under numerous environmental conditions.

Shujun, Junjie, (2004) expressed that a fully fortified automotive air-conditioning test system contains five main modules including a compressor, a condenser, an orifice tube, an evaporator and an accumulator. Here, R-134a is being used as refrigerant. The constant performance, evaporator cooling volume, usage of compressor power, whole mass flow rate, vapor mass flow rate, liquid mass flow rate and oil in flow, compressions and temperatures of refrigerant at each element, both inlet and outlet are being evaluated and examined with the difference of the temperatures at evaporator and condenser and refrigerant charge. The organized experimental results acquired from this real-size test system describe the relations of the stated limitations in an automotive air conditioning system, which establish a useful source for automotive air conditioning systems plan and exploration. The two-phase flow dimensions, which have been recognized in this work, deliver an extremely essential tool in order to analyse system performance.

THERMOPHYSICAL PROPERTIES

Higashi (2010) studied about the thermo physical properties of HFO-1234yf and HFO-1234ze (f). HFO-1234yf is expected as the new source of zero-ozone depletion potential (ODP) and low global warming potential (GWP). The critical temperature, critical density, and critical pressure are some the thermo physical properties of the refrigerants, which can be used to develop the air conditioners. HFO-1234yf has low GWP, but softly flammable and not stable with the double bond. The acentric factor acts as the important factor to predict the thermo physical properties by the state of cubic equation. Based on the analysis of author, critical temperature of HFO-1234yf is low when compared to the HFO-1234ze (f). The critical molar volume of HFO -1234yf is higher than the critical molar volume of HFO-1234ze (f).

Esbri et al (2013) studied about the experimental analysis of R1234yf as a drop in replacement for R134a in a vapor compression system. The thermo physical properties of R1234yf and R134a are similar and R1234yf is referred as the good choice to replace the R134a in the application of refrigeration and air conditioning. The refrigerant R1234yf does not contain chlorine and hence the ODP is zero. The global warming potential is low and the emissions of 1234yf could not increase in trifluoroacetic acid (TFA) concentrations of rain water. Authors have analyzed that the cooling capacity of R1234yf is lower when compared to the R134a.

Karber, Abdelaziz and Vineyard (2012) studied about the experimental performance of R1234yf, as a drop in replacement for R134a in domestic refrigerators. R-1234yf has lower coefficient of performance (COP) and less capacity than the R-134a. R1234yf and R134a performance are similar in lubricant miscibility and polymer compatibility. The energy consumption of R1234yf is higher, when compared to the R134a. R1234yf has less capacity and higher coefficient of performance than the R-410a. R-1234yf acts as the leading component to replace the R-134a in the applications of automobile sector. The refrigerant R-1234yf has the global warming potential (GWP) of 4. It has better compatibility of material and it is also similar to the R-134a.

Paul, Sarkar and Mandal (2013) studied the environmental impacts of halogenated refrigerants and their alternatives. R1234yf are used as the direct expansions for the automobile manufacturer. It also offers low direct global warming potential (GWP) of four on the basis of 100 years. The reproductive testing of R1234yf had been found to be incomplete, but the results for acute and sub acute were favorable. The production of R1234yf requires stringent process control to prevent the containment of toxicity.

Aute and Radermacher (2014) studied about the standardized polynomials for fast evaluation of refrigerant thermo physical properties. The fundamental equations of state (EOS) are used to calculate the thermo physical properties of the refrigerants. Thermo physical properties include the thermodynamic and transport properties. Pressure range of R1234yf is very low when compared to the R32, R410A, R407C and R407F. The enthalpy range of R1234yf is moderately higher than the R407F but lower than R32, R410A, and R407C. Saturated liquid properties speed up, saturated vapor properties sped up and Ph-flash speed up is lower, when compared to the refrigerants R32, R410A, R407C and R407F.

Bolaji (2014) studied the performance of the eco-friendly hydrofluroolefins and dimethyl ether refrigerants in refrigeration systems. Hydrofluroolefins (R1234yf and R1234ze) acts as the substitute for R134a in the standard refrigeration system of vapor compression. R1234yf has exhibited the very close volumetric capacity of refrigerating with the R134a. The coefficient of performance (COP) of R1234yf is slightly lower by 6.1%. The molecular mass of refrigerants R1234yf is higher than the R134a and RE 170. The critical temperature of R1234yf is lower than the R134a, R1234ze and RE170. The latent heat of R1234yf is lower than the R134a, R1234ze and RE 170. The ozone depletion potential (ODP) is zero for the refrigerants R1234yf, RE170, R1234ze and R134a. Global warming potential (GWP) of R1234yf is lower than the R134a and R1234ze.

Atalay and Coban (2015) studied about modeling of thermodynamic properties for pure refrigerants and refrigerant mixtures by using the Helmholtz equation of state and cubic spline curve fitting method. Authors have analyzed that the temperature has varied between the 233K and 448K for R1234yf refrigerant. Absolute and mean deviations were evaluated for the thermodynamics properties of R1234yf for all the three regions. The uncertainty density, entropy and enthalpy for r1234yf are within 0.5%. The critical temperature of R1234yf is very low, when compared to the R410A. The critical parameters and the physical properties of R1234yf are used to reduce the molar Helmholtz energy.

RESEARCH GAP

This study examines about the influence of refrigerant R134a and R1234yf properties on the automobile HVAC core. The research gap predicted in this study is that, there is no study on the combination of R134a and R1234yf on the automobile HVAC evacuator core. Many studies have focused only on the thermodynamic and thermo physical properties of the refrigerants. There is only limited studies existing, based on their influence and other properties. This study also predicted that the R1234yf risks are very small when compared to risk of vehicle fire that has viewed as acceptable by the general public. Many conventional refrigerants can be replaced with the R1234yf for the case of mobile air conditioners. R1234yf is less flammable than the propane. Moreover, the R1234yf is also referred to as the low-GWP refrigerants, which are also considered as the most promising elements for the conventional HFC refrigerants (Axell, 2013). R1234yf have a very low flame propagation velocity, in which its effect of buoyancy on the quenching measurement of distance is very large. R134a acts as the common refrigerants used in domestic sized heat pumps. Coefficient of performance (COP), energy efficiency, power consumption, and exergy efficiency are better in R134a when compared to other refrigerants.

CONCLUSIONS

Refrigerant (R134a/R1234YF) has acquired much attention worldwide. Investigations were done in this study to know the thermo physical properties and process of R134a and R1234yf. This study also predicted many terms and factors to know the importance of these refrigerants R134a and R1234yf. R134a has higher global warming potential, and it can also be replaced with the eco-friendly refrigerant. According to the evaluation of ANSI standard 97 of R1234yf with POE oils of refrigeration and other materials, no evidence of break down has been shown. R-1234yf requires high work of compressor than the R134a. It has a shorter run time to complete the cycle of compressor when compared to other refrigerants. Global warming potential is very high for R134a than the R1234yf. This study will be useful for the researchers to know more about the influence of refrigerant R134a and R1234yf.

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